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Mental health problems during puberty: Tanner stage-related differences in specific symptoms. The TRAILS study

Albertine J. Oldehinkel [a,b,*], Frank C. Verhulst [b], Johan Ormel [a]

[a] Interdisciplinary Center for Psychiatric Epidemiology and Groningen Graduate School Medical Sciences,, University Medical Center Groningen, CC 72, P.O. Box 30001, 9700 RB Groningen, The Netherlands

[b] Department of Child and Adolescent Psychiatry, Erasmus University Medical Center – Sophia Children's Hospital, P.O. Box 2060, 3000 CB Rotterdam, The Netherlands

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A B S T R A C T

The aim of this study was to investigate associations between specific mental health problems and pubertal stage in (pre)adolescents participating in the Dutch prospective cohort study TRAILS (first assessment: $N = 2230$, age 11.09 ± 0.56, 50.8% girls; second assessment: $N = 2149$, age 13.56 ± 0.53, 51.0% girls). Mental health was assessed by the Youth Self-Report, pubertal (Tanner) stage by parent-rated drawings of secondary sex characteristics. Overall, higher Tanner stages were related to more reported tiredness, irritability, rule-breaking behaviors, and substance use; and fewer fears and somatic complaints. Girls showed increases in social uncertainty, depressed mood, and worries; boys a decrease in self-criticism. Increasing problems during puberty were mostly related to the process of physical maturation, whereas decreasing problems were rather related to general age-related developments. Pubertal timing was associated with different symptoms than pubertal status or age. Puberty seems to affect girls more negatively than boys.

Introduction

The transition from child to adolescent is characterized by major biological, psychological, and social challenges and opportunities. These developmental processes are believed to be reflected in alterations in emotional states, attitudes, and behavioral patterns (Buchanan, Eccles, & Becker, 1992). In fact, evidence points to early adolescence as a critical period in terms of the pathogenesis of internalizing and externalizing mental health problems (e.g., Hamburg, 1974). It is a time where depression rates start to rise, especially in girls (e.g., Angold, Costello, & Worthman, 1998; Hankin et al., 1998), where the expression of fears and anxiety tends to alter from separation and danger to social evaluation (Weems & Costa, 2005; Westenberg, Drewes, Goedhart, Siebelink, & Treffers, 2004), where (male) aggression and delinquency have been found to peak (Barker, Tremblay, Nagin, Vitaro, & Lacourse, 2006; Flannery, Rowe, & Gulley, 1993), and where substance use starts to increase substantially (Costello, Sung, Worthman, & Angold, 2007; Patton et al., 2004).

While research on temporal changes in psychiatric syndromes and disorders has been very elucidating, diagnostic classifications may not capture the nature of the changes adequately because of their heterogeneous nature. Even if the total number of problems within a specific diagnostic category remains constant over time, changes in within-category symptom patterns are still possible and may be highly relevant for prevention and intervention strategies. Hence, the most accurate

* Corresponding author. Interdisciplinary Center for Psychiatric Epidemiology, University Medical Center Groningen, CC 72, P.O. Box 30001, 9700 RB Groningen, The Netherlands. Tel.: +31 50 361 4550; fax: +31 50 361 9722.
E-mail addresses: a.j.oldehinkel@med.umcg.nl (A.J. Oldehinkel), f.verhulst@erasmusmc.nl (F.C. Verhulst), j.ormel@med.umcg.nl (J. Ormel).

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way to investigate the patterns of mental health problems over time is to examine changes at the level of the specific emotions and behaviors that underlie higher-order diagnostic entities.

The aim of the present study was to investigate specific mental health problems in relation to pubertal stage, in a large longitudinal population sample of (pre)adolescent boys and girls. There is a paucity of knowledge about pubertal changes in specific emotional and behavioral problems, particularly with regard to boys. To the best of our knowledge, this study is the first to provide a comprehensive overview of such changes in both boys and girls.

Puberty refers to the activation of the hypothalamic–pituitary–gonadal axis that culminates in gonadal maturation, whereas adolescence is a more general term which also includes the psychological and social transition between childhood and adulthood (Flannery et al., 1993; Sisk & Foster, 2004). These processes are closely linked together, as is illustrated by the fact that hormone levels can modify the effects of socialization and environment on behavior (Udry, 2000), but not completely overlapping. To explore to what extent the biological process of maturation contributed to early adolescent changes in mental health, we examined if effects of pubertal stage remained significant after adjusting for chronological age. Apart from pubertal stage and chronological age itself, emotions and behaviors may also be affected by timing of puberty as compared to peers (e.g., Ge, Conger, & Elder, 1996; Graber, Lewinsohn, Seeley, & Brooks-Gunn, 1997; Kaltiala-Heino, Kosunen, & Rimpelä, 2003; Kaltiala-Heino, Marttunen, Rantanen, & Rimpelä, 2003). Therefore, effects of early and late maturation were examined as well, and effects of pubertal stage adjusted for pubertal timing.

Method

Sample

The TRacking Adolescents' Individual Lives Survey (TRAILS) is a prospective cohort study of Dutch (pre)adolescents, with the aim to chart and explain the development of mental health from preadolescence into adulthood (Huisman et al., 2008). The present study involves data from the first (T1) and second (T2) assessment wave of TRAILS, which ran from March 2001 to July 2002 and September 2003 to December 2004, respectively.

TRAILS participants were selected from five municipalities in the North of the Netherlands, including both urban and rural areas. All children born between 10-01-1989 and 09-30-1990 (first two municipalities) or 10-01-1990 and 09-30-1991 (last three municipalities) were eligible for inclusion, provided that their schools were willing to cooperate and that they were able to participate in the study. Over 90% of the schools accommodating 3145 children agreed to participate in the study. A small proportion (6.7%) of these children were excluded because of mental or physical incapability or language problems. Of the remaining 2935 children, 76.0% ($N = 2230$, mean age = 11.09, SD = 0.56, range 10–12, 50.8% girls) were enrolled in the study (i.e., both child and parent agreed to participate). Teacher reports were available for 40.7% of the nonresponders and revealed that they did not differ from responders with respect to the prevalence of problem behavior, nor regarding associations between sociodemographic variables and mental health outcomes, but were more likely to be boys, to have a low socio-economic background, and to perform poorly at school (De Winter et al., 2005).

Of the 2230 baseline participants, 96.4% ($N = 2149$, 51.0% girls) participated in the first follow-up assessment (T2), which was held two to three years after T1 (mean number of months 29.44, SD = 5.37, range 16.69–48.06). Mean age at T2 was 13.56 (SD = 0.53, range 12–15). Attrition was not associated with psychopathology (Huisman et al., 2008).

Measures

Data collection

The present study was based on questionnaire and interview data from (pre)adolescents and parents. Both at T1 and T2, parents (usually the mother, >95%) filled out a questionnaire at home. In addition, they were interviewed at T1. The (pre)adolescents were measured at school, where they filled out questionnaires in groups, under the supervision of one or more TRAILS assistants.

Emotional and behavioral problems

Emotional and behavioral problems were assessed at T1 and T2, with the Youth Self-Report (YSR, Achenbach, 1991; Verhulst & Achenbach, 1995). We chose to use a self-report measure of mental health because the amount of time parents and children spend together and reported closeness decrease when children enter adolescence (Larson & Richards, 1991), which is likely to affect the validity of parent-reported problem behaviors (Sourander, Helstelä, & Helenius, 1999; Verhulst & Van der Ende, 1992). The YSR is one of the most commonly used self-report questionnaires in current child and adolescent psychiatric research. It contains a list of 120 behavioral and emotional problems, which can be rated as 0 = not true, 1 = somewhat or sometimes true, or 2 = very or often true in the past six months. The YSR includes two broadband domains, internalizing and externalizing problems. Internalizing problems include anxious/depressed behavior, withdrawn/depressed behavior, and somatic complaints; while externalizing problems involve aggressive and rule-breaking behavior. Scale scores represent mean items scores. Valid YSR data were available for 98.2% ($N = 2190$) of the T1 and 97.3% ($N = 2091$) of the T2 participants.

Pubertal stage

At both T1 and T2, stage of pubertal development was assessed by parent ratings of schematic drawings of secondary sex characteristics associated with the five standard Tanner stages of pubertal development (Marshall & Tanner, 1969, 1970), with stage 1 corresponding to infantile and stage 5 to complete puberty (Tanner & Whitehouse, 1982). Parent reports of schematic drawings are generally considered an acceptable way to assess physical development, and have demonstrated adequate validity (Coleman & Coleman, 2002). Parental ratings of the Tanner stage were missing or unreliable in 2.5% of the T1 participants and 30.4% of the T2 participants; more often in boys than in girls (T1: $\chi^2_1 = 11.64$, $p = .001$; T2: $\chi^2_1 = 81.54$, $p < .001$). Missing Tanner data were not related to self-reported internalizing ($t = -1.12$, $p = .12$) or externalizing ($t = -0.37$, $p = .71$) problems at T1, nor to internalizing problems at T2 ($t = 1.47$, $p = .14$), but adolescents with missing data at T2 had more externalizing problems ($t = -3.66$, $p < .001$). In order to prevent biased estimates of Tanner-related changes, missing Tanner data were imputed based on related variables (insofar as they were available). Separate estimations were made for boys and girls. T1 variables used were age, height, weight, Tanner stage at T2 and number of months between T1 and T2. Together, these variables explained 48.5% of the variance in girls, and 6.3% in boys. The low percentage of variance explained in boys is most probably due to a lack of dispersion at T1: the vast majority of the boys were still in Tanner stage 1 or 2 at T1. T2 estimates were based on age, height, weight, Tanner stage at T1, number of months between T1 and T2, and data from the Pubertal Development Scale (PDS, Petersen, Crockett, Richards, & Boxer, 1988), which was filled out by the adolescents at T2. Together, these variables explained 52.0% of the variance in girls, and 39.1% in boys. Imputation was not feasible in one T1 and eight T2 participants, leaving 2189 cases available for analysis (i.e., with data on both mental health and Tanner stage) at T1, and 2083 cases at T2. Table 1 shows the gender-specific distribution of Tanner stages at T1 and T2. At both waves, girls were in a more advanced pubertal stage than boys (T1: $\chi^2_4 = 166.10$, $p < .001$; T2: $\chi^2_4 = 305.48$, $p < .001$).

Adolescents were labeled as early- or late-maturing if they had a Tanner stage with a prevalence of less than 10 percent in their gender and age group. This implied that early maturing boys ($n = 98$) had Tanner stage 3 or higher at age 10 or 11, stage 4 or higher at age 12, or stage 5 at age 13 or 14. Early maturing girls ($n = 62$) were defined as those with Tanner stage 4 or higher at age 10 or 11, or stage 5 at age 12. Late-maturing boys ($n = 38$) had Tanner stage 1 at age 13 or higher, while late-maturing girls ($n = 36$) had Tanner stage 1 at age 12 or higher, or stage 2 at age 14 or higher.

Statistical analysis

Because the joint distribution of T1 and T2 Tanner stage covered the whole range of stages, we combined the data from both assessment waves in the analysis, using a quasi cross-sectional design. While in an actual cross-sectional study all observations are assumed to be independent, in our data set most adolescents were represented twice: once with T1 data and once with T2 data. To account for the fact that observations within the same individual are not independent, we used the cluster option of the statistical program Stata (StataCorp., 2003). This option relaxes the independence assumption and requires only that the observations be independent across the clusters (i.e., across different individuals). A p-value smaller than .01 was considered statistically significant.

First, we calculated the total YSR internalizing and externalizing problem scales scores (based on the means of the individual items), and tested effects of gender, Tanner stage, and the interaction of gender and Tanner stage by linear regression analysis. We used a robust estimator of variance, which requires no assumptions about the distribution of the dependent variable. The main effects of gender and Tanner stage were entered as a first step, and their interaction secondly. In case of significant interaction effects, post hoc analyses were performed to test puberty-related changes in each of the two genders separately.

Subsequently, we examined each of the individual items, using an ordered logit model to account for the ordinal nature of the item score (0 = not true, 1 = somewhat or sometimes true, 2 = very or often true). As in the previous set of analyses, main effects of gender and Tanner stage were entered first, and their interaction in a second step; while post hoc analyses were performed to assess in which of the two genders the effect of Tanner stage was significant in case of significant interactions of gender by Tanner stage.

To examine whether associations between YSR-problems and Tanner stage were related to puberty, chronological age, or both, the item-specific analyses were repeated with age added to the set of predictor variables. If the effect of Tanner stage had been found to be different for boys and girls, the adjusted analyses were stratified by gender. To investigate to what extent the results might be due to pubertal timing rather than Tanner stage itself, we examined the effects of early or late maturation

Table 1
Distribution of Tanner stage at T1 (mean age 11.09) and at T2 (mean age 13.56).

Tanner stage	Number (percentage)			
	Boys T1 ($n = 1072$)	Boys T2 ($n = 1013$)	Girls T1 ($n = 1117$)	Girls T2 ($n = 1070$)
1	353 (32.9%)	61 (6.0%)	327 (29.3%)	19 (1.8%)
2	660 (61.6%)	278 (27.4%)	513 (45.9%)	119 (11.1%)
3	55 (5.1%)	475 (46.9%)	214 (19.2%)	339 (31.7%)
4	2 (0.2%)	145 (14.3%)	58 (5.2%)	468 (43.7%)
5	2 (0.2%)	54 (5.3%)	5 (0.4%)	125 (11.7%)

on YSR-problems, with gender-stratified analyses if gender modified the effect of pubertal timing significantly. Because early maturation tends to coincide with relatively young and late maturation with older ages, the effects were adjusted for age. Finally, we adjusted the effects of Tanner stage (if any) for pubertal timing, to investigate confounding by early or late maturation.

Results

Overall changes

Overall, internalizing problems were more prevalent in girls ($B = 0.09$, $p < .001$) and externalizing problems in boys ($B = -0.06$, $p < .001$). Externalizing problems increased with Tanner stage in both boys and girls ($B = 0.04$, $p < .001$; interaction n.s.). Puberty-related trends in internalizing problems showed gender differences, as indicated by a significant interaction of gender and Tanner stage ($B = 0.03$, $p < .001$). While the estimated number the problems remained approximately constant in girls ($B = 0.01$, $p = .09$), they decreased in boys ($B = -0.03$, $p < .001$) across Tanner stages (see Fig. 1).

Changes in specific problems

Analyses at the item level revealed more variegated patterns. Means and test results of all items are presented in Appendix A; items that showed a significant ($p < .01$) increase or decrease are listed in Table 2.

The majority of the items that were positively associated with Tanner stage in the total sample reflected sexual thoughts and behavior (thinking about sex, obscene language), tiredness (overtired, lack of energy), autonomy and rule-breaking behavior (keeping things to self, disobedience, breaking rules, truancy, stealing), or substance use (alcohol, tobacco, drugs). Furthermore, we found an increase in depressed mood and mood changes, worries and social concerns in girls, but not in boys. Except for screaming, no symptoms increased in boys but not in girls. Specific fears and somatic complaints tended to decrease with increasing Tanner stage. In addition, boys in high Tanner stages reported to cry less and to be less bothered by self-criticism and tension than boys in low Tanner stages. None of the symptoms decreased in girls but not in boys. A noteworthy trend, though not statistically significant, is an increase of suicidal ideation during puberty ($B = 0.12$, $p = .03$).

Table 3 shows the six most prevalent problems at Tanner stages 1 and 4/5 (Tanner stage 4 and 5 were combined because of the relatively low number of boys in Tanner stage 5). Both in boys and in girls, swearing and the use of obscene language were common, particularly at higher Tanner stages. Somatic complaints, nervousness, and fears were relatively common at stage 1, while stubbornness/irritability and a preference for older kids became more dominant features at stage 4/5. In boys, the patterns of problems shifted towards more externalizing behaviors during puberty: while at Tanner stage 1 half of the most prevalent problems came from the internalizing domain, there were no internalizing problems among the top six at stages 4/5 anymore. The most remarkable shift in girls was the emergence of self-consciousness and mood changes instead of fear-related problems.

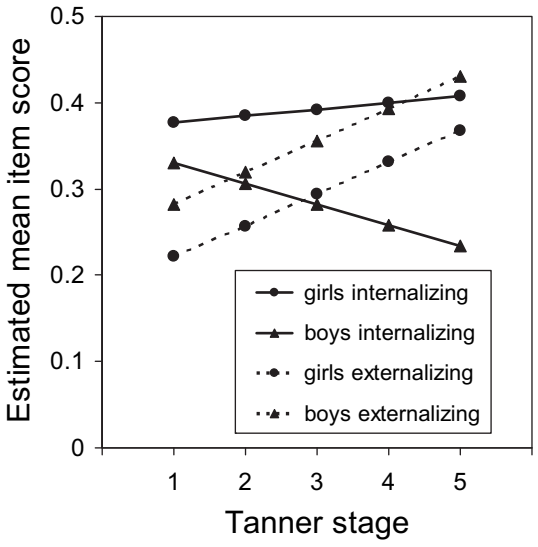

Fig. 1. Estimated internalizing and externalizing problems by Tanner stage.

Table 2
Youth Self-Report items that were significantly associated with Tanner stage.

Increasing with Tanner stage	Decreasing with Tanner stage
Internalizing problems	
Secretive, keep things to self	Fears certain animals or situations
Underactive, lacks energy	Fears going to school
Overtired without obvious reason	Too fearful or anxious
Feels dizzy or light-headed	Nightmares
	Aches or pains (no stomach or head)
	Eye problems
	Stomachaches or cramps
	Vomiting
♀: Too shy or timid	♂: Cries a lot
♀: Unhappy, sad, or depressed	♂: Feels (s)he has to be perfect
♀: Worries	♂: Feels worthless or inferior
♀: Self-conscious, easily embarrassed	♂: Nervous, highstrung, tense
	♂: Feels too guilty
	♂: Headaches
	♂: Nausea, feels sick
Externalizing problems	
Stubborn, irritable	Teases a lot
Mean to others	Hangs around with others who get in trouble
Disobedient at home	
Disobedient at school	
Unusually loud	
Thinks about sex too much	
Breaks the rules	
Prefers being with older kids	
Steals outside the home	
Truancy	
Swears, uses obscene language	
Drinks alcohol without permission	
Smokes/chews tobacco or takes snuffs	
Uses drugs	
♂: Screams a lot	
♀: Mood changes	

♂: only in boys; ♀: only in girls.

Effects of chronological age and pubertal timing

Adjusted for chronological age, Tanner stage remained significantly or trend-wise ($p < .05$) associated with virtually all problems that showed an increase during puberty (see Table 2), except overtiredness and being mean to others. As opposed to problems that increased during puberty, problems that decreased across Tanner stages were mostly associated with age rather than Tanner stage: except for crying (in boys), the effects of Tanner stage were not significant anymore after adjusting for age. Hanging around with others who get in trouble appeared negatively associated with age ($B = -0.22$, $p < .001$), and positively with Tanner stage ($B = 0.11$, $p = .009$). An overview of all test results is presented in Appendix B (available online as supplementary data).

With a few exceptions, early maturation was associated with other problems than Tanner stage itself, namely, complaints of being unloved, thoughts about killing self, eye problems, destroying own things, physically attacking people, temper

Table 3
Boys' and girls' most prevalent problems (mean score) at Tanner stages 1 and 4/5.

Boys		Girls	
Tanner stage 1	Tanner stage 4/5	Tanner stage 1	Tanner stage 4/5
Swearing, obscene language (0.64)	Swearing, obscene language (1.00)	Headaches (0.79)	Stubborn, irritable (0.83)
Headaches (0.62)	Prefers being with older kids (0.65)	Stomachaches (0.72)	Swearing, obscene language (0.81)
Argues a lot (0.57)	Stubborn, irritable (0.64)	Nervous, highstrung, tense (0.60)	Headaches (0.75)
Not guilty after misbehaving (0.56)	Not guilty after misbehaving (0.61)	Fears animals, situations, etc. (0.60)	Prefers being with older kids (0.73)
Stomachaches (0.55)	Thinks about sex too much (0.52)	Stubborn, irritable (0.58)	Mood changes (0.70)
Nervous, highstrung, tense (0.52)	Argues a lot (0.52)	Nightmares (0.57)	Self-conscious (0.70)

tantrums, and running away from home (effects adjusted for age). Feeling worthless/inferior was positively associated with early maturation (total group) and negatively with Tanner stage (boys), while a preference for older kids was positively associated with both Tanner stage and early maturation. Late maturation was associated with crying a lot. For additional information regarding early and late maturation see Appendix C (available online). As might be expected from the relative independence of the effects of Tanner stage and pubertal timing, adjusting for pubertal timing largely unaffected the effects of Tanner stage. In general, effects tended to become somewhat larger rather than the opposite, except for the association with dizziness ($B = 0.08$, $p = .02$), which just failed to reach statistical significance (details can be found in Appendix D, available online).

Discussion

Early adolescence is the life phase of physical maturation, but also of other age-related psychological or socio-cultural developments. Each of these developments involves risks and opportunities, and may affect mental health problems. Furthermore, a physical development which is out of pace with same-aged peers may pose an additional challenge. In this study, we examined which specific emotions and behaviors are associated with pubertal stage, taking into account chronological age and pubertal timing. Tanner stage was related to both increasing and decreasing symptom rates. With only a few exceptions, positive associations remained (marginally) significant after adjusting for chronological age, while negative associations appeared due to age rather than physical maturation. To the best of our knowledge, we are the first to address effects of pubertal status, age, and pubertal timing simultaneously with regard to a comprehensive set of mental health problems. The surplus value of our approach is that it reveals patterns of change that may otherwise be overlooked. Furthermore, we found a tendency to become less self-critical in boys, a finding which has not been reported before. The findings are described in more detail below.

General Tanner stage-related patterns

The period in which a child turns into an adolescent is characterized by many interrelated developments, among which hormonal and morphological changes, a changing socio-cultural status, and an increase in self-regulatory capacity. Each of these developments may affect mental health problems and, as we will illustrate below, probably did so in our sample. Findings with regard to the total sample are discussed below, while gender-specific trends are discussed in the next section. Please note that we used a quasi cross-sectional design in this study, and that any inferences regarding developmental changes are based on the – in our view reasonable – assumption that cross-sectional effects of pubertal stage and age are representative of developmental changes.

One of the defining characteristics of puberty is an increase in gonadal steroid hormone secretion, which not only fuels sexual feelings and motivation (e.g., Flannery et al., 1993; Sisk & Foster, 2004), but may also change the nature of sensory experiences and autonomic (re)activity (e.g., Aloisi, 2003; Beatty, 1979), especially when the body is still adjusting to the changes and hormone cycles may be irregular (e.g., Brooks-Gunn & Warren, 1989; Buchanan, 1991; Olweus, Mattsson, Schalling, & Löw, 1980). The increase in reported sexual thoughts and behaviors and in irritability found in our sample seems a logical consequence of these hormonal developments. Likewise, the increase in tiredness could result from the adjustment to changing hormone concentrations (Buchanan et al., 1992). The fact that these symptoms were not just associated with Tanner stage, but also with age (adjusted for Tanner stage) suggests that socio-cultural factors (e.g., peer behaviors) play a role as well.

Adolescents reach physical maturity years before they attain the social status of adulthood, a phenomenon which has been described as the maturity gap (Galambos, Barker, & Tilton-Weaver, 2003; Moffitt, 1993). In their search for social adulthood, adolescents caught up in the maturity gap may engage in behaviors that prove their independence and help to obtain the admiration of peers. Support to the notion of a maturity gap is lent by an increase in symptoms reflecting autonomy and rule violations (e.g., disobedience, truancy), which could not be explained by age. Similar patterns were found in previous studies (Achenbach & Edelbrock, 1981; Barker et al, 2006; Bongers, Koot, Van der Ende, & Verhulst, 2004; Flannery et al., 1993). The desire to show independence and to be admired by peers could also explain the association of Tanner stage with a preference for older friends, and the use of alcohol, tobacco, and drugs (Patton et al., 2004). Substance use was related to age as well, which may signal the fact that it starts to become a socially accepted behavioral option in adolescence (e.g., Wiium, Torsheim, & Wold, 2006).

Parts of the prefrontal cortex continue to mature until adulthood (Casey, Geidd, & Thomas, 2000; Gogtay et al., 2004; Murphy, Eisenberg, Fabes, Shepard, & Guthrie, 1999). Effortful control, that is, the capacity to self-regulate attention, emotions, and behavior (Kochanska, Murray, & Harlan, 2000; Rothbart, Ellis, Rueda, & Posner, 2003), demands complex cognitive operations, involving the prefrontal cortex (Nelson, Leibenluft, McClure, & Pine, 2005). Hence, self-regulatory capacities keep developing throughout adolescence. Effortful control has been found to be inversely related to fearfulness (e.g., Oldehinkel, Hartman, De Winter, Veenstra, & Ormel, 2004; Oldehinkel, Hartman, Ferdinand, Verhulst, & Ormel, 2007), suggesting that increases in self-regulation may reduce the tendency to experience fears. Indeed, consistent with previous evidence (e.g., Gullone & King, 1997; Westenberg et al., 2004), reported fears and fearfulness declined across pubertal stages. This decline was unrelated to the process of physical maturation, but exclusively due to chronological age. Besides growing self-regulatory capacities, the decline in fears may also be explained by changes in the expression of fears when children grow

older (e.g., Weems & Costa, 2005). The increase in worrying suggests that such a trade-off might actually occur. A final explanation for the decline in fears may be a reduced willingness to report behaviors that are considered childish, which could also underlie the decrease in boys' crying.

Unexpectedly, we found a decline in somatic complaints without known medical cause. Tentatively, children learn to better interpret and express their feelings and emotions in early adolescence, which reduces the need to somatize. However, this is contradicted by previous findings that rates of pain and somatization increased during puberty, particularly in girls (e.g., LeResche, Mancl, Drangsholt, Saunders, & Von Korff, 2005).

Gender-specific developments during puberty

Morphological changes during puberty and associated changes in social interactions may lead to increased self-consciousness and concerns about peer evaluations (e.g., Abe & Suzuki, 1986; Simmons & Blyth, 1987; Westenberg et al., 2004). Girls typically conceptualize puberty-related changes in body size and weight negatively (e.g., Davison & McCabe, 2006). In line with this, social uncertainties like shyness and self-consciousness increased with Tanner stage in girls. Girls also showed a rise in worrying and depressed mood with increasing pubertal stage. This may be explained by the fact that young adolescents tend to encounter many situations a person with high interpersonal sensitivity may worry or feel bad about, such as shifts in peer coalitions and unrequited crushes (Ge, Lorenz, Conger, Elder, & Simons, 1994; Rubin, Bukowski, & Parker, 1998; Rudolph & Hammen, 1999). This applies to both boys and girls, but girls tend to become more sensitive to (interpersonal) stressful experiences during adolescence (Cyranowski, Frank, Young, & Shear, 2000; Oldehinkel, Ormel, Veenstra, De Winter, & Verhulst, 2008). Taken together, the patterns of change observed in our study are very consistent with the often-reported increase in female depression rates in early adolescence (e.g., Angold et al., 1998). Angold, Costello, Erkanli, and Worthman (1999) proposed that this increase is mainly triggered by changes in testosterone and estrogen levels.

There were no gender-specific increases in boys, but we did observe a tendency for boys to become less self-critical. Although these findings do not seem implausible, we are not aware of other reports of similar gender-specific trends. Leadbeater, Kuperminc, Blatt, and Hertzog (1999) found that early adolescents' self-critical vulnerabilities were higher in boys than in girls and declined in both genders. Contrastingly, Birndorf and her group (Birndorf, Ryan, Auinger, & Aten, 2005) reported a decrease in self-esteem between grade 8 and grade 10. The present study is, to our knowledge, the first to address the association between self-criticism and pubertal stage in a large population sample of early adolescent boys. Self-criticism has been associated with higher levels of (internalizing and) externalizing problems, presumably because self-critical individuals are more likely to engage in deviant behaviors to build up their sense of self or deflect criticism (e.g., Leadbeater et al., 1999; Wild, Flisher, Bhana, & Lombard, 2004). While this may be true cross-sectionally, our results seem to contradict a developmental association between self-criticism and externalizing behaviors, at least in boys.

Effects of pubertal timing

With a few exceptions, pubertal timing (that is, early or late maturation) appeared associated with other problems than Tanner stage in itself. Early maturing adolescents felt more lonely, as evidenced by feelings of being unloved and inferior, thoughts about killing self, and running away from home. This is conceivable considering that deviation from normative timing implies a lack of same-aged friends to discuss one's changing body with (Kaltiala-Heino, Kosunen, et al., 2003). A preference for older kids fits into that picture. Another explanation could be derived from the fact the early puberty may be caused by obesity (Lee et al., 2007), which is known to be associated with loneliness and low self-esteem (e.g., Strauss, 2000). Early maturers also reported more uncontrolled behaviors such as temper tantrums and destroying things. This could be the result of the unfortunate combination of puberty-related hormonal perturbations with (still) a relatively immature brain.

Late maturers had fewer problems than early maturers, at least, fewer effects were significant. Perhaps this is because late-maturing adolescents can anticipate and adapt to the changes while observing earlier maturing peers (Kaltiala-Heino, Marttunen, et al., 2003). However, it may also be due to the lower power to detect differences in this group.

Most likely, symptoms that are associated with the timing of puberty are more transient than symptoms associated with maturation itself or with age. To the best of our knowledge, however, this has never been explored empirically.

Strengths and limitations

Our study has a number of notable assets, among which the large population-based sample covering all pubertal stages, the inclusion of both internalizing and externalizing problems, and the fact that we took into account chronological age and pubertal timing. Furthermore, the analysis of specific emotions and behaviors rather than (broad- or narrowband) scale scores revealed puberty-related trends that would have remained obscure otherwise.

There are also limitations. First, ideally adolescents should be measured at each Tanner stage, regardless of age, and developmental trends investigated with individual growth models. The TRAILS study design, in which the two assessment waves were on average two and a half years apart, precluded analysis of individual growth curves and resulted in an over-representation of early maturers in the high Tanner stages, and late maturers in the low ones. However, with a few exceptions, pubertal timing appeared to be associated with other emotional and behavioral problems than Tanner stage itself, and it did not confound the associations reported. Secondly, Tanner stage ratings were primarily based on parent reports, if necessary

complemented by self-report data. Examinations by health professionals would probably have led to more accurate ratings (Coleman & Coleman, 2002) and consequently more power to detect significant differences. Because we used different informants for Tanner stage and mental health problems, systematic biases are not very likely. A third limitation of this study is that we relied solely on questionnaire-based data, which provide a valuable measure of individuals' consistent behaviors in multiple settings (Lengua, 2002), but may also involve reporter bias and other measurement problems. In other words, (changes in) reported problems do not necessarily reflect actual (changes in) problem levels. It should be noted, however, that these measurement problems are not restricted to questionnaire data. A final limitation is that the individual YSR items used in this study were not psychometrically tested as such. The measurement error of the individual YSR scores is most likely greater than that of scale scores based on multiple indicators. If anything, this has probably affected the results conservatively, that is, masked minor trends over time.

Conclusions

Our results show that puberty-related trends in internalizing and externalizing problems do not concern all items of these broadband domains, but only a subset of problems which are specifically affected by the psychobiological or socio-cultural developments in this phase of life. Even if the total number of problems is not associated with pubertal stage, the pattern may still alter, as is evidenced most clearly in girls' internalizing problems: girls' total number of internalizing problems remain approximately constant, but there is a relative shift – at least at the population level – from specific fears and somatic problems towards self-consciousness and negative affect. Whether these changes reflect different expressions of the same underlying vulnerability (in the same individuals) or hint at discontinuity of mental health problems (i.e., distressed children turn into healthy adolescents and vice versa) cannot be determined on the basis of our results, but previous research suggest both (heterotypic) continuity and discontinuity in early adolescence (e.g., McGee, Feehan, Williams, & Anderson, 1992).

It is remarkable that while virtually all rises in mental health problem were at least partly related to the process of physical maturation, decreasing problems rates were related to age rather than pubertal development. Assuming that pubertal development mainly reflects hormonal and morphological developments, and age cognitive and socio-cultural ones, this provides clues about the mechanisms involved in the etiology of each specific symptom.

Overall, this study confirms previous reports suggesting that puberty affects girls more negatively than boys (e.g., Angold et al., 1998; Nottelman, Inoff-Germain, Susman, & Chrousos, 1990). Boys are overrepresented in early-onset neuropsychiatric disorders such as autism and attention deficit disorder with hyperactivity. Hence, girls are better off during childhood with respect to psychiatric problems, but wholly or partly seem to lose that advantage during adolescence (Rutter, Caspi, & Moffitt, 2003).

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Appendix A. Items means of the youth self-report, by gender and Tanner stage.

Item		Item means					Coefficient (p)[a]	
		Tanner stage					Gender (girls)	Tanner stage[b]
		1	2	3	4	5		
Internalizing								
Likes little	Boys	0.33	0.32	0.24	0.32	0.46	−0.13 (.10)	−0.03 (.33)
	Girls	0.29	0.29	0.24	0.27	0.28		

Appendix A (*continued*).

Item		Item means					Coefficient (p)[a]	
		Tanner stage					Gender (girls)	Tanner stage[b]
		1	2	3	4	5		
Would rather be alone than with others	Boys	0.36	0.38	0.36	0.33	0.39	0.13 (.08)	0.03 (.37)
	Girls	0.37	0.41	0.39	0.39	0.48		
Refuses to talk	Boys	0.23	0.26	0.19	0.19	0.16	−0.25 (.003)	−0.04 (.34)
	Girls	0.19	0.18	0.17	0.19	0.21		
Secretive, keeps things to self	Boys	0.28	0.39	0.43	0.35	0.55	0.24 (.001)	0.25 (<.001)
	Girls	0.35	0.41	0.47	0.59	0.75		
Too shy or timid	Boys	0.40	0.38	0.39	0.37	0.41	0.69 (<.001)	♂ −0.04 (.39)
	Girls	0.53	0.58	0.59	0.64	0.76		♀ 0.14 (<.001)
Underactive, slow moving, lacks energy	Boys	0.33	0.32	0.29	0.34	0.36	0.28 (<.001)	0.09 (.004)
	Girls	0.33	0.38	0.36	0.43	0.52		
Unhappy, sad, or depressed	Boys	0.17	0.23	0.17	0.15	0.18	0.59 (<.001)	♂ −0.05 (.36)
	Girls	0.28	0.31	0.31	0.33	0.52		♀ 0.13 (.002)
Withdrawn, not involved with others	Boys	0.34	0.39	0.33	0.29	0.32	−0.18 (.01)	−0.01 (.64)
	Girls	0.29	0.34	0.30	0.27	0.36		
Cries a lot	Boys	0.35	0.30	0.17	0.12	0.14	0.82 (<.001)	♂ −0.42 (<.001)
	Girls	0.46	0.47	0.41	0.41	0.47		♀ −0.05 (.14)
Fears certain animals, situations, etc.	Boys	0.36	0.36	0.30	0.26	0.23	0.75 (<.001)	−0.09 (.003)
	Girls	0.60	0.56	0.51	0.56	0.57		
Fears going to school	Boys	0.07	0.08	0.03	0.03	0.02	0.33 (.02)	−0.17 (.003)
	Girls	0.10	0.08	0.07	0.08	0.04		
Fears might think or do something bad	Boys	0.24	0.27	0.24	0.21	0.25	0.42 (<.001)	−0.00 (.94)
	Girls	0.33	0.33	0.34	0.34	0.40		
Feels (s)he has to be perfect	Boys	0.50	0.43	0.35	0.28	0.38	0.25 (<.001)	♂ −0.21 (<.001)
	Girls	0.45	0.48	0.44	0.50	0.54		♀ 0.03 (.34)
Complains no one loves him/her	Boys	0.25	0.28	0.18	0.20	0.27	0.21 (.01)	−0.00 (.97)
	Girls	0.27	0.26	0.29	0.28	0.35		
Feels worthless or inferior	Boys	0.17	0.20	0.12	0.12	0.13	0.40 (<.001)	♂ −0.17 (.009)
	Girls	0.23	0.20	0.22	0.25	0.36		♀ 0.10 (.03)
Nervous, highstrung, or tense	Boys	0.52	0.51	0.45	0.38	0.40	0.44 (<.001)	♂ −0.16 (.001)
	Girls	0.60	0.61	0.57	0.62	0.65		♀ 0.02 (.62)
Too fearful or anxious	Boys	0.23	0.22	0.13	0.13	0.16	0.63 (<.001)	−0.13 (<.001)
	Girls	0.35	0.32	0.27	0.29	0.30		
Feels too guilty	Boys	0.26	0.29	0.21	0.16	0.18	0.28 (<.001)	♂ −0.16 (.004)
	Girls	0.28	0.32	0.30	0.30	0.41		♀ 0.04 (.30)
Self-conscious, easily embarrassed	Boys	0.34	0.36	0.40	0.37	0.46	0.65 (<.001)	♂ 0.08 (.09)
	Girls	0.45	0.54	0.57	0.66	0.85		♀ 0.25 (<.001)
Thinks about killing self	Boys	0.09	0.09	0.07	0.06	0.11	0.08 (.54)	0.12 (.03)
	Girls	0.07	0.08	0.09	0.11	0.19		
Worries	Boys	0.30	0.34	0.39	0.35	0.36	0.58 (<.001)	♂ 0.11 (.02)
	Girls	0.40	0.49	0.51	0.66	0.82		♀ 0.29 (<.001)
Nightmares	Boys	0.44	0.45	0.26	0.22	0.14	0.60 (<.001)	♂ −0.39 (<.001)
	Girls	0.57	0.58	0.45	0.41	0.45		♀ −0.20 (<.001)
Feels dizzy or lightheaded	Boys	0.26	0.30	0.27	0.28	0.36	0.51 (<.001)	0.08 (.009)
	Girls	0.40	0.40	0.43	0.48	0.52		
Overtired without obvious reason	Boys	0.23	0.27	0.34	0.35	0.32	0.16 (.04)	♂ 0.16 (.002)
	Girls	0.23	0.26	0.38	0.48	0.60		♀ 0.35 (<.001)
Aches or pains (no stomach or head)	Boys	0.37	0.36	0.26	0.32	0.35	0.29 (<.001)	−0.18 (<.001)
	Girls	0.48	0.45	0.30	0.32	0.38		
Headaches	Boys	0.62	0.67	0.53	0.49	0.45	0.49 (<.001)	♂ −0.19 (<.001)
	Girls	0.79	0.76	0.69	0.74	0.78		♀ −0.04 (.29)
Nausea, feels sick	Boys	0.45	0.45	0.31	0.28	0.25	0.48 (<.001)	♂ −0.26 (<.001)
	Girls	0.54	0.53	0.47	0.53	0.48		♀ −0.03 (.41)

(*continued on next page*)

Appendix A (*continued*).

Item		Item means					Coefficient (p)[a]	
		Tanner stage					Gender (girls)	Tanner stage[b]
		1	2	3	4	5		
Eye problems	Boys	0.20	0.17	0.07	0.11	0.02	0.49 (<.001)	−0.43 (<.001)
	Girls	0.29	0.25	0.16	0.09	0.13		
Skin problems	Boys	0.19	0.18	0.14	0.21	0.20	0.67 (<.001)	−0.04 (.28)
	Girls	0.32	0.34	0.31	0.29	0.25		
Stomachaches or cramps	Boys	0.55	0.53	0.40	0.37	0.30	0.69 (<.001)	−0.17 (<.001)
	Girls	0.72	0.69	0.64	0.64	0.58		
Vomiting	Boys	0.28	0.29	0.18	0.16	0.08	0.14 (.08)	−0.34 (<.001)
	Girls	0.34	0.32	0.22	0.15	0.14		
Externalizing								
Argues a lot	Boys	0.57	0.58	0.48	0.49	0.61	−0.00 (.95)	−0.08 (.01)
	Girls	0.57	0.54	0.50	0.55	0.46		
Mean to others	Boys	0.37	0.36	0.40	0.39	0.48	−0.47 (<.001)	0.15 (<.001)
	Girls	0.22	0.25	0.30	0.35	0.37		
Demands a lot of attention	Boys	0.49	0.50	0.53	0.43	0.48	−0.31 (<.001)	0.02 (.46)
	Girls	0.40	0.39	0.40	0.44	0.46		
Destroys his/her own things	Boys	0.19	0.21	0.17	0.16	0.27	−0.57 (<.001)	−0.03 (.49)
	Girls	0.14	0.10	0.11	0.10	0.17		
Destroys others' belongings	Boys	0.11	0.11	0.09	0.11	0.05	−0.95 (<.001)	−0.12 (.06)
	Girls	0.05	0.05	0.03	0.03	0.05		
Disobedient at home	Boys	0.40	0.40	0.38	0.46	0.54	0.03 (.62)	0.10 (.001)
	Girls	0.37	0.41	0.39	0.49	0.45		
Disobedient at school	Boys	0.32	0.39	0.40	0.41	0.49	−0.54 (<.001)	0.18 (<.001)
	Girls	0.19	0.26	0.27	0.35	0.34		
Gets in many fights	Boys	0.35	0.39	0.30	0.37	0.41	−1.25 (<.001)	0.02 (.67)
	Girls	0.12	0.14	0.12	0.15	0.15		
Physically attacks people	Boys	0.13	0.14	0.11	0.12	0.16	−0.85 (<.001)	−0.03 (.55)
	Girls	0.05	0.07	0.04	0.07	0.05		
Screams a lot	Boys	0.22	0.25	0.33	0.35	0.45	0.41 (<.001)	♂ 0.24 (<.001)
	Girls	0.36	0.37	0.37	0.43	0.40		♀ 0.06 (.13)
Stubborn, irritable	Boys	0.52	0.53	0.57	0.66	0.59	0.45 (<.001)	0.19 (<.001)
	Girls	0.58	0.66	0.67	0.81	0.91		
Mood changes	Boys	0.38	0.44	0.38	0.42	0.52	0.37 (<.001)	♂ 0.04 (.34)
	Girls	0.44	0.45	0.52	0.69	0.75		♀ 0.30 (<.001)
Suspicious	Boys	0.23	0.28	0.28	0.21	0.23	0.14 (.06)	0.06 (.06)
	Girls	0.26	0.29	0.25	0.36	0.33		
Teases a lot	Boys	0.34	0.34	0.22	0.22	0.29	−0.56 (<.001)	−0.21 (<.001)
	Girls	0.22	0.21	0.16	0.13	0.13		
Temper tantrums or hot temper	Boys	0.40	0.42	0.39	0.41	0.39	−0.44 (<.001)	0.03 (.39)
	Girls	0.29	0.27	0.26	0.31	0.38		
Threatens people	Boys	0.09	0.10	0.08	0.10	0.14	−1.05 (<.001)	0.08 (.23)
	Girls	0.04	0.03	0.03	0.05	0.06		
Unusually loud	Boys	0.31	0.38	0.38	0.46	0.59	−0.40 (<.001)	0.16 (<.001)
	Girls	0.25	0.26	0.31	0.35	0.38		
Drinks alcohol without permission	Boys	0.08	0.12	0.18	0.26	0.25	−0.60 (<.001)	0.42 (<.001)
	Girls	0.04	0.06	0.10	0.17	0.20		
Not guilty after misbehaving	Boys	0.56	0.58	0.53	0.54	0.79	−0.38 (<.001)	0.02 (.39)
	Girls	0.42	0.50	0.49	0.45	0.54		
Breaks the rules	Boys	0.40	0.43	0.40	0.44	0.50	−0.55 (<.001)	0.10 (.001)
	Girls	0.24	0.26	0.31	0.36	0.35		
Hangs around with others in trouble	Boys	0.47	0.48	0.42	0.47	0.50	−0.01 (.87)	−0.08 (.006)

Appendix A (*continued*).

Item		Item means					Coefficient (p)[a]	
		Tanner stage					Gender (girls)	Tanner stage[b]
		1	2	3	4	5		
Girls	0.53	0.47	0.42	0.41	0.46			
Lying or cheating	Boys	0.32	0.32	0.30	0.21	0.32	−0.31 (<.001)	−0.06 (.07)
	Girls	0.22	0.27	0.24	0.20	0.25		
Prefers being with older kids	Boys	0.41	0.40	0.47	0.55	0.89	0.02 (.81)	♂ 0.22 (<.001)
	Girls	0.37	0.38	0.46	0.70	0.86		♀ 0.37 (<.001)
Runs away from home	Boys	0.07	0.07	0.05	0.01	0.09	−0.33 (.02)	0.03 (.67)
	Girls	0.05	0.03	0.03	0.06	0.09		
Sets fires	Boys	0.21	0.18	0.23	0.17	0.20	−1.92 (<.001)	0.01 (.79)
	Girls	0.04	0.03	0.03	0.03	0.04		
Steals at home	Boys	0.09	0.07	0.06	0.10	0.11	−0.42 (.004)	0.02 (.78)
	Girls	0.04	0.05	0.05	0.06	0.05		
Steals outside the home	Boys	0.06	0.06	0.06	0.06	0.09	−0.84 (<.001)	0.19 (.008)
	Girls	0.02	0.02	0.03	0.05	0.04		
Swearing or obscene language	Boys	0.64	0.74	0.87	1.02	0.95	−0.49 (<.001)	0.32 (<.001)
	Girls	0.49	0.61	0.69	0.79	0.87		
Thinks about sex too much	Boys	0.20	0.29	0.39	0.55	0.45	−1.15 (<.001)	0.39 (<.001)
	Girls	0.07	0.11	0.14	0.22	0.30		
Smokes/chews tobacco or takes snuffs	Boys	0.04	0.04	0.14	0.20	0.18	−0.46 (.002)	0.60 (<.001)
	Girls	0.01	0.04	0.06	0.13	0.22		
Truancy	Boys	0.07	0.07	0.08	0.10	0.16	−0.31 (.02)	0.28 (<.001)
	Girls	0.05	0.04	0.05	0.11	0.12		
Uses drugs	Boys	0.03	0.02	0.04	0.07	0.04	−0.93 (<.001)	0.54 (<.001)
	Girls	0.00	0.01	0.01	0.03	0.05		

[a] As obtained in an ordered logit model with the item as dependent variable.
[b] Gender-specific analyses were performed if the interaction of gender by Tanner stage was significant ($p < .01$). ♂ = boys, ♀ = girls.

Appendix. Supplementary data

Supplementary data associated with this article can be found in online at doi:10.1016/j.adolescence.2010.01.010.

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